AD-A060 323 CIVIL ENGINEERING LAB (NAVY) PORT HUFNEME CALIF F/G 13/9

ANACAPA ISLAND SPLIT PIPE INSPECTION OF JUNE 1977 AND APRIL 197--ETC(U)

SEP 78 W R TAUSIG, R L BRACKETT

UNCLASSIFIED CEL-TN-1525 NL

1 OF 1
ADA
060323

END
DATE
FILMED
12 78
DDC

END
DATE
FILMED
12 78
DDC

Technical Note

TN no. N-1525

title: ANACAPA ISLAND SPLIT PIPE INSPECTION OF JUNE 1977 AND APRIL 1978

author: W. R. Tausig and R. L. Brackett

date: September 1978

sponsor: Naval Facilities Engineering Command

program nos: YF52.556.999.01.301

DEPARTMENT OF THE NAVY
CIVIL ENGINEERING LABORATORY

CIVIL ENGINEERING LABORATORY

NAVAL CONSTRUCTION BATTALION CENTER
Port Hueneme, California 93043

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: N-1525	2. GOVT ACCESSION NO.: DN587008
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*): 6 ANACAPA ISLAND SPLIT PIPE INSPECTION OF JUNE 1977 AND APRIL 1978,	5. TYPE OF REPORT & PERIOD COVERED: Not Final; Sep 1974 – Jun 1978
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 W. R. Tausig and R. L. Brackett	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: CIVIL ENGINEERING LABORATORY, Naval Construction Battalion Center, Port Hueneme, California 93043 391 111	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62759N; YF52.556.999.01.301
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Facilities Engineering Command, Alexandria, Virginia 22332	12. REPORT DATE: 11 September 1978
	13. NUMBER OF PAGES: 28
14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*): 16 F52556 17 YF52556999	15. SECURITY CLASS. (*of this report*): Unclassified
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

12 32 p.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

14 CEL-TN-1525

18. SUPPLEMENTARY NOTES

9 Technical note, Sep 74-Jun 78,

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Cables, pipes, inshore areas, protection, corrosion, fasteners, stabilization systems, split-pipe system, rock bolts, and blind bolts.

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

The U. S. Navy currently maintains and operates numerous underwater power and signal cables. Most of these cables utilize split pipe systems to protect the cable from damage in the surf zone and when crossing exposed rocky seafloors. Past experience has shown that the hardware used to install the split pipe system lacks the reliability and maintenance-free operation required for the life of the cables. Based on previous experience with cable failures, the areas determined to be in greatest need of investigation are (continued) CONT!

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

78 10 19 045

391 111

20. Continued

CONT'

fasteners for holding the split pipe halves together, immobilization of the pipe, and cathodic protection for the entire system. As a result, CEL tested prototype and commercially available hardware components which appeared to be suitable replacements for the existing split pipe hardware. The candidate hardware was then used in a 300-ft-long test section of split pipe installed March 1976 at Anacapa Island, to be inspected during a five-year period. Results of the CEL hardware tests, Anacapa pipe installation, and first inspection are documented in TN-1498. This report is a follow-up to TN-1498 and presents the results of the test installation inspections for June 1977 and April 1978; the second and third inspections to be made since the March 1976 installation was completed.

Library Card

Civil Engineering Laboratory
ANACAPA ISLAND SPLIT PIPE INSPECTION OF JUNE 1977 AND APRIL 1978, by W. R. Tausig and R. L. Brackett
TN-1525 28 p. illus September 1978 Unclassified

1. Split-pipe systems 2. Underwater cables I. YF52.556.999.01.301

The U. S. Navy currently maintains and operates numerous underwater power and signal cables. Most of these cables utilize split pipe systems to protect the cable from damage in the surf zone and when crossing exposed rocky seafloors. Past experience has shown that the hardware used to install the split pipe system lacks the reliability and maintenance-free operation required for the life of the cables. Based on previous experience with cable failures, the areas determined to be in greatest need of investigation are fasteners for holding the split pipe halves together, ommobilization of the pipe, and cathodic protection for the entire system. As a result, CEL tested prototype and commercially available hardware components which appeared to be suitable replacements for the existing split pipe hardware. The candidate hardware was then used in a 300-ft-long test section of split pipe installed March 1976 at Anacapa Island, to be inspected during a five-year period. Results of the CEL hardware tests, Anacapa pipe installation, and first inspection are documented in TN-1498. This report is a follow-up to TN-1498 and presents the results of the test installation inspections for June 1977 and April 1978; the second and third inspections to be made since the March 1976 installation was completed.

Table of Contents

1.0 INTRODUCTION

Underwater power and signal cables are of great importance to the Navy. In most cases, split pipe systems are used to protect these cables from damage in the nearshore and surfzone regions. However, experience has shown that hardware used in installing these split pipe systems is often unreliable. Previous attempts to improve the hardware have been confined to in-the-field trial-and-error procedures using off-the-shelf hardware.

Under the sponsorship of the Naval Facilities Engineering Command (NAVFACENGCOM), a project was undertaken in July 1974 by the Civil Engineering Laboratory (CEL) to develop improved hardware and methods for the maintenance and repair of existing split pipe protected cables. To meet this objective, CEL investigated: different types of fasteners for holding the split pipe together, methods for immobilization of the cable, and methods for cathodically protecting the entire system. The hardware components that showed promise during laboratory tests were then used in a 300-foot-long open ocean test installation on the south side of Anacapa Island, California. These components are being inspected and monitored approximately semi-annually for a five-year period.

This report presents the results of the test installation inspections for June 1977 and April 1978; the second and third inspections to be made since the March 1976 installation was completed. (Due to adverse winter weather conditions, the inspection scheduled for November 1977 was not accomplished). Installation procedures and results of the first inspection are reported in reference 1.

2.0 BACKGROUND

To determine the suitability for long-term installations, the candidate hardware components were installed on 98 sections of split pipe located on the south side of Anacapa Island. Details of the pipe installation and hardware description are given in Appendix A, taken from reference 1.

During each of the semi-annual inspections, the following items are monitored:

(a) effects of cathodic protection on the entire system

(b) amount of marine growth on the fasteners*

* The amount of marine growth observed indicates the amount of abrasion present. The abrasive effects of the sand driven by the local surge keeps the marine growth to a minimum. In addition, large amounts of marine growth will increase the hydrodynamic drag on a cable installation, and thus affect the design of the immobilization system.

(c) effects of hydrodynamic forces on the pipe and long-term performance of the rock bolt immobilization, and

(d) serviceability and corrosion resistance of the 3 types of fasteners.

In November 1976, the first of ten planned inspections was accomplished. The results of this inspection revealed numerous broken jumper cables, resulting in the loss of cathodic protection for all pipe sections except sections 45 through 78. All other components were found to be in good condition. Details of the first inspection are discussed in Appendix B, also taken from reference 1.

3.0 EFFECTS OF CATHODIC PROTECTION

3.1 June 1977

Visual inspection of the pipe installation in June 1977 revealed that numerous jumper cables were missing despite repairs to the jumpers during the November 1976 inspection. This was primarily due to the fact that the hardware selected for attaching the zinc anodes and jumper cables to the split pipe installation was mechanically inadequate to withstand the wave action of the open ocean environment. All jumper cables were broken or missing between pipe sections 1 through 12. Additional broken jumpers were found between pipe sections 29 and 30, 34 and 35, 39 and 40, 41 and 42, 44 and 45, 60 and 61, 86 and 87, 87 and 88. Anodes normally connected to pipe sections 10 and 30 were missing. The anode connected to pipe section 30 was replaced during this inspection. The wire connecting pipe section 90 to its anode was found broken, but reconnected during this inspection.

Galvanic potential readings were taken with an underwater voltmeter. The results are presented in Figure 1. Note that pipe sections 43 through 77 are the only sections cathodically protected. The remaining pipe sections are unprotected due to the numerous broken jumper and anode cables.

3.2 April 1978

In addition to the jumper cables reported broken or missing during the prior inspection, broken jumpers were found between pipe sections 12 through 31, and 33 through 45. The anode cables connected to pipe sections 10, 50 and 90 were also found broken. The anode connected to pipe section 30, which was replaced during the June 1977 inspection, was again missing. The only remaining working anode was located at pipe section 70. This anode was weighed in water to determine the amount of anode consumption. These data are presented in Table 1.

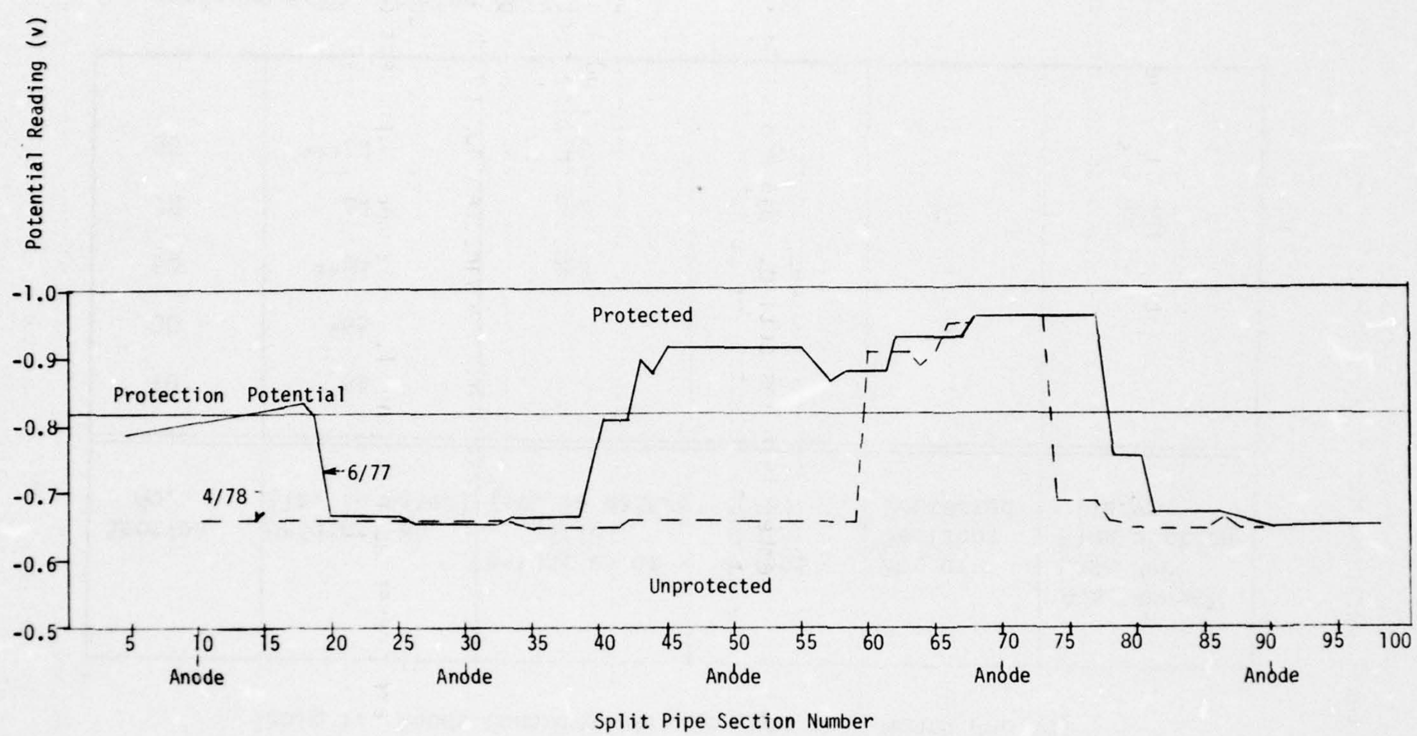


Figure 1. Cathodic Protection Potential

Table 1. Anode Consumption Rate (For a 25-Month Period)

Section No.	Original Wt. (lb, in water)	Weight as of 4/78 (lb, in water)	Weight Loss (lb)	No. of Sections Protected	Avg. Annual Loss Per Pipe Section (lb/yr)
10	64	-	-	-	-
30	*65	-	-	-	-
50	**64	53	11	-	-
70	64	42	22	13	0.81
90	***64	58	6	-	-

* replaced 6/77, missing 4/78
** broken 4/78
*** reconnected 6/77, broken 4/78

Galvanic potential readings were again obtained over the entire pipe installation. Results of these data are included in Figure 1. Note that due to further jumper cable and anode failures, only pipe sections 60 through 73 are cathodically protected.

Figure 2a shows an example of a cathodically protected, BOM fastener from the June 1977 inspection. Figure 2b shows an example of a cathodically protected BOM fastener from the April 1978 inspection, after 25 months of submersion. Note in comparing these figures that there is little or no sign of corrosion on the fasteners.

4.0 EFFECTS OF MARINE GROWTH

4.1 June 1977

Visual inspection and photographic documentation of the fasteners in June 1977 revealed only moderate amounts of marine growth. All fasteners could be readily identified without removing any growth. In areas where the pipe sections crossed predominately sandy bottom, the fasteners showed very little or no marine growth. This is probably due to "abrasive" effects of the sand driven by the local surge.

4.2 April 1978

Visual and photographic inspection of the fasteners in April 1978 revealed heavy marine growth. In many cases, the type of fastener could not be readily identified without first brushing away the growth.

Figure 3a shows typical marine growth encountered in June 1977. The fastener is a Hi-Shear bolt located on pipe section 53. In comparison, Figure 3b shows the heavy marine growth encountered in April 1978. This fastener is also a Hi-Shear bolt.

5.0 EFFECTS OF HYDRODYNAMIC FORCES AND IMMOBILIZATION

5.1 June 1977

Inspection of the installation revealed that from the period March 1976 to June 1977, no pipe damage was suffered from hydrodynamic forces. In addition, all rockbolts were found intact.

5.2 April 1978

Inspection of the installation revealed that from the period June 1977 through April 1978, the pipe installation suffered heavy damage to its shore end. This was due to extremely heavy storm

Figure 2a. Cathodically protected fastener from pipe section 57, June 1977.

Figure 2b. Cathodically protected fastener from pipe section 71, April 1978.

Figure 3a. Moderate marine growth on Hi-Shear fastener from pipe section 53, June 1977.

Figure 3b. Heavy marine growth on Hi-Shear fastener from pipe section 80, April 1978.

wave forces. Figure 4 shows the maximum significant wave heights in the pipe installation area for the winter of 1978. Pipe sections 2 through 10 were dislodged and separated from the rest of the installation. Only pipe section 1 remained rockbolted to the shore. All pipe sections beyond section 10 (at a water depth of 10 feet out to 42 feet) remained intact. The four rockbolts located on pipe sections 2 and 3 failed to hold during the storm. In addition, the Hi-Shear fasteners on sections 2 through 10 failed to hold these pipe halves securely together. A failure analysis of the pipe damage is discussed in section 7.

6.0 EFFECTS OF CORROSION

6.1 June 1977

Visual inspection of each pipe fastener in June 1977 revealed no failures due to excessive corrosion. Fasteners that were not cathodically protected showed signs of corrosion. However, there were no signs of loose pipe halves due to corrosive failures.

6.2 April 1978

Visual inspections of April 1978 of the pipe fasteners for the undamaged sections 11 through 98 revealed no evidence of failure due to corrosion. Close inspection of the damaged pipe sections 2 through 10 revealed that the primary cause of failure was due to corrosion of the mild steel Hi-Shear fasteners. Section 7 gives the failure analysis. Figure 5a shows a photograph taken in June 1977 of a BOM fastener which is not cathodically protected. Figure 5b shows an unprotected BOM fastener taken in April 1978. The corrosion products were significantly increased during the 10-month period between inspections.

7.0 FAILURE ANALYSIS

In May 1978, seven of the damaged pipe sections 2 through 10 were recovered for closer inspection and failure analysis. Figure 6 shows four views of the damaged installation and broken pipe. Note the large amount of tangled wire and armor from the exposed multi-conductor cable. Pipe sections 2 through 5 were found intact but severed completely from the rest of the installation. These sections were installed with stainless steel Hi-Shear fasteners. Close examination of these fasteners revealed that the pipe flange holes had enlarged around the fastener due to the galvanic interaction between the cast iron pipe and stainless steel fastener. Although none of the stainless fasteners were missing, the pipe halves were loose enough to allow the bell end of section 2 to open and slip off pipe section 1. Figure 7 shows the gap created between pipe

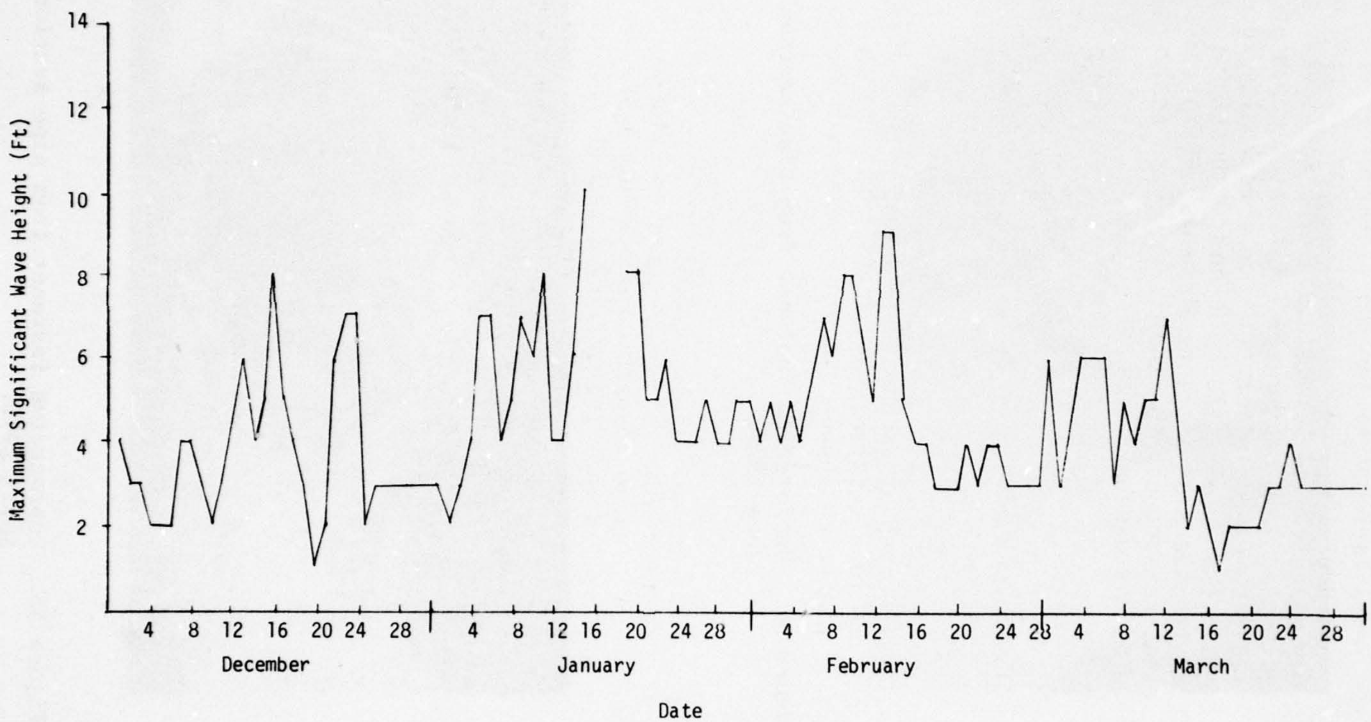


Figure 4. Significant Wave Heights

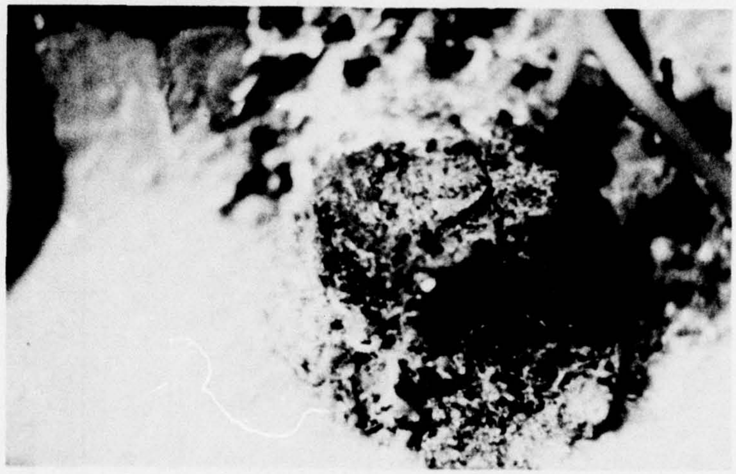


Figure 5a. Unprotected fastener from pipe section 87, June 1977.

Figure 5b. Unprotected fastener from pipe section 86, April 1978.

Figure 6a. Damaged pipe showing tangled multiconductive cable.

Figure 6b. Damaged pipe separated from installation.

Figure 6c. Cable end extending from pipe section 11.

Figure 6d. Disassembled pipe half on the seafloor.

halves due to the fasteners slipping through the enlarged flange halves. The combination of corrosion and high winter wave loads was enough to cause the rockbolts to fail on pipe sections 2 and 3. Figure 8 shows the remains of two recovered rockbolts in which one had severed and one had pulled out.

Pipe sections 6 through 10, which were installed with mild steel Hi-Shear fasteners, were found to be completely disassembled (refer to Figure 6d). The majority of these fasteners were missing from the pipe halves. Close examination of the recovered fasteners revealed that corrosion between the steel pipe and steel fastener decreased the diameter of the flared end of the fastener by about 0.1 inches. Failure occurred when these fasteners corroded enough to slip through the pipe flange holes. Figure 9 shows the mode of failure for the mild steel Hi-Shear fasteners.

In addition, it was noted that all of the mild steel nuts and bolts in pipe sections 2 through 10 were completely missing. They apparently corroded and vibrated loose.

The only fasteners that remained intact were the BOM fasteners which were installed beginning with Section 11. These fasteners have enlarged swaged ends, which resist slippage due to corrosion. Figure 10 shows a comparison of the enlarged swaged end of a BOM fastener with the swaged end of a Hi-Shear fastener.

Table 2 lists the experimental fasteners (in order of mechanical integrity) along with their failure modes after 25 months of testing.

8.0 CONCLUSIONS

1. Results to date indicate that the cathodic protection system, where it remained intact, provides sufficient protection for the pipe sections and fasteners. The average anode consumption rate was found to be 0.81 pound per year per pipe section.

2. Failure analysis has shown that both split pipe and fastener (whether mild steel or stainless steel) must be cathodically protected.

3. The exposed jumper and anode cables are identified as the system components most susceptible to damage. Once the cables are broken, the cathodic protection is lost, and corrosive failure follows.

4. Due to its enlarged locking swaged head, the BOM fastener was found to be mechanically superior to the Hi-Shear fastener in resisting corrosive loosening.

5. Without cathodic protection, the BOM fastener appears to maintain its mechanical integrity longer than any other type fastener used to date - including stainless steel nuts and bolts.

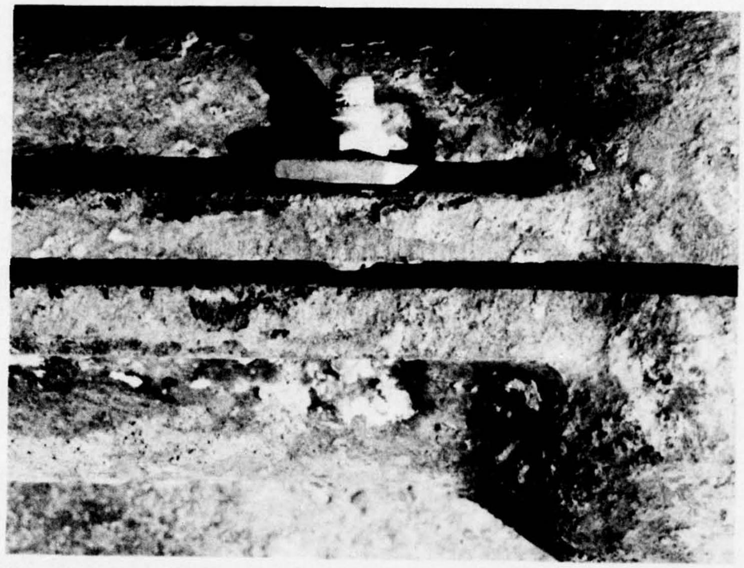


Figure 7. Gap in pipe halves due to slippage of Hi-Shear stainless steel fasteners.

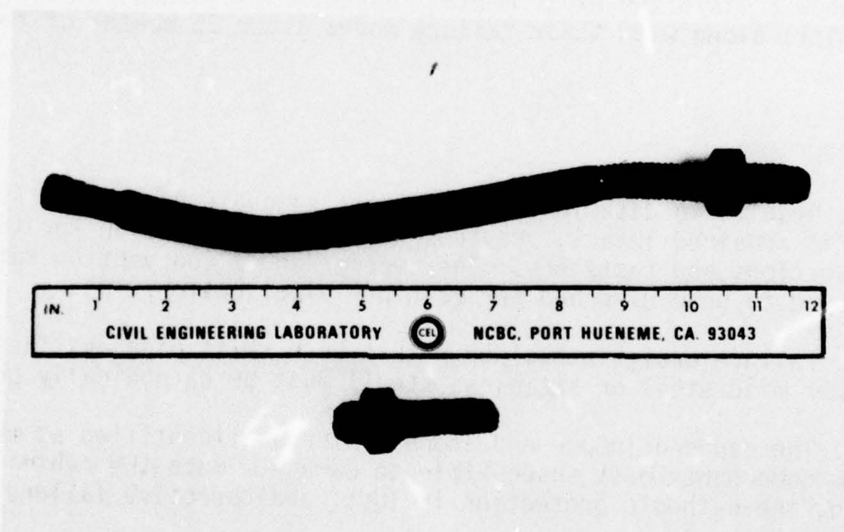


Figure 8. Recovered rockbolts.

23

Figure 9. Corroded Hi-Shear steel fasteners slipping through the pipe flange.

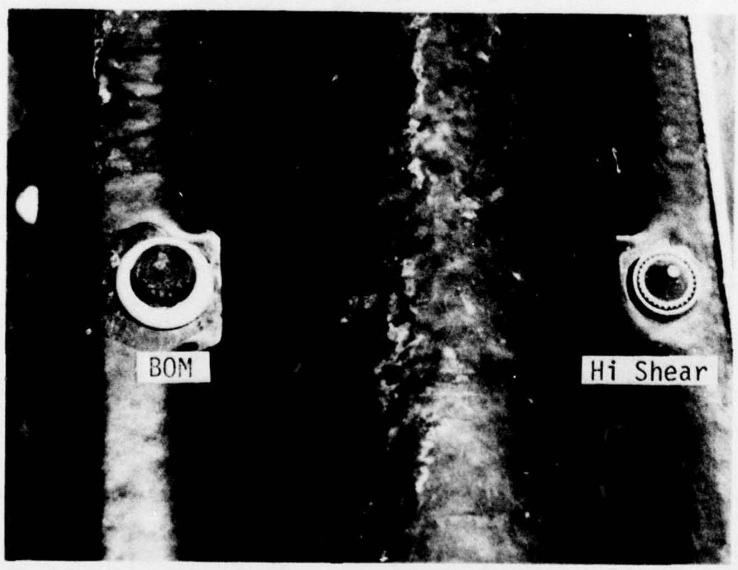


Figure 10. Comparison of the swaged end of a BOM and Hi-Shear fastener.

Table 2.

Fastener	Failure Mode
1. BOM	No failures
2. Hi-Shear Stainless Steel	Corrosion of pipe around fasteners causing pipe halves to loosen.
3. Hi-Shear Mild Steel	Decrease in fastener diameter due to corrosion, allowing fastener to pull out of pipe flange.
4. Nuts and Bolts - Mild Steel	Corrosion and vibration loosening, allowing fastener to fall out of pipe halves.

9.0 REFERENCE

1. Brackett, R. L. and Tausig, W.R. (1977). Improved Hardware and Techniques for Maintenance and Repair of Split-Pipe Protected Cables, Civil Engineering Laboratory. Technical Note 1498, Port Hueneme, CA, August 1977.

APPENDIX A

LONG-TERM TEST INSTALLATION (MARCH 1976)

Based on the results of the Laboratory and harbor tests, the following hardware components were selected for long-term testing:

Fasteners. . . . . .Huck BOM

Hi Shear Stainless Steel

Hi Shear Mild Steel

Immobilization. . . . . . Philips Wedge Masonry Anchor, 5/8-in. diam. x 12 in. long.

Cathodic protection. . . . . Sacrificial anode consisting of:

five 75-lb zinc anodes

99 jumper cables

Coal tar epoxy coating on split pipe

To determine the suitability of these candidate system components to perform effectively in an actual split pipe installation, a 300-ft-long test section was installed that will be inspected semiannually for a 5-yr period. This installation serves two purposes. First, it provides an opportunity for military divers to install split pipe using the new hardware and tools, and second, it provides an opportunity to observe the condition of the candidate hardware over a long period when subjected to the open ocean environment.

Site Selection

The test site selection was based on the following criteria.

(1) The site should be close enough to Port Hueneme to allow semiannual inspections without high deployment costs.

(2) Because of the short length of the test section (300 ft), a steep depth gradient is desirable.

(3) The area should be predominantly rock to allow full evaluation of the immobilization system.

(4) The site should be protected to allow for installation and inspection by divers, but it should be subject to the effects of winter storm conditions.

(5) Underwater visibility should be at least 30 ft to allow for photographic documentation.

The selected site is located on the south side of Anacapa Island at coordinates 34°0'15"N latitude, 119°23'30"W longitude. After preliminary selection, the site was surveyed, and the following conditions were found:

- Bottom material . . . . . Vesicular Basalt, 80%; Sand, 20%
- Depth gradient . . . . . 14% Slope (0 to -42 ft)
- Visibility . . . . 30 to 90 ft
- Swell . . . . Minimum, 1/2 ft
  Maximum, 8 to 10 ft (late summer and fall)

Installation

The actual installation was accomplished in six phases: (1) mooring installation, (2) assembly of 75 ft of split pipe on warping tug, (3) deployment of cable and first 75 ft of split pipe, (4) deployment and assembly of remaining 225 ft of split pipe by divers, (5) installation of rock bolts and anodes, and (6) inspection and documentation.

Because of the heavy surge conditions that exist near shore, the first 75 ft (25 sections) of pipe were assembled around the cable on board the CEL warping tug. A 12-in. H-beam was first tack-welded to the deck, and the pipe and cable were assembled in the upper channel This served to stabilize the pipe during transit to the test site, and it also acted as a guide during deployment of the pipe and cable.

The bolting sequence for the first 25 sections was:

Section No.	Type of Bolt	No. of Rock Bolts
1	Mild Steel	2
2-5	Hi Shear Stainless	4
6-10	Hi Shear Mild Steel	0
11-15	Huck BOM	2
16-20	Hi Shear Stainless	0
21-25	Hi Shear Mild Steel	0

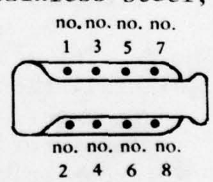
This phase of the installation also allowed all of the tools and power sources to be checked out prior to deployment and the divers to familiarize themselves with the tools and their operation prior to using them in the open ocean.

After the split pipe and cable had been deployed at the test site, the remaining 225 ft of split pipe were assembled on the seafloor by divers.

The procedures used for assembling the test installation were:

(1) One type of fastener was to be used for five consecutive split pipe sections.

(2) Sequence of fasteners: Huck BOM, Hi Shear Stainless Steel, and then Hi Shear Mild Steel.



(3) Bolt holes no. 5 and no. 6 would not contain fasteners (Rock bolts would be installed during the immobilization phase of the installation)

(4) Jumper cables were to be connected between sections of pipe using bolt holes no. 1 and no. 7.

The rock bolts were always installed in pairs in holes no. 5 and no. 6 in the split pipe flange. This prevented the pipe from twisting and applying a bending load to the bolt. The bolt pairs were to be installed in every sixth section of pipe; however, the presence of sand and loose rocks in some areas precluded absolute adherence to this spacing.

Five anodes were attached, one each to sections 10, 30, 50, 70, and 90. A 20-ft-long cable connected each 75-lb zinc anode to the pipe. The anodes were placed as far from the pipe as possible and in a rocky area where they wouldn't be covered with sand. After the rock bolts and anodes were installed, all of the remaining flange holes were filled with mild steel nuts and bolts and Hi Shear fasteners. Table A-1 lists the position of the fasteners in each pipe section.

Table A-1. Position of Fasteners.

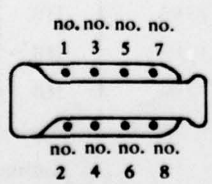
Section	Flange Holes 1-4,7,8	5	6	Section	Flange Holes 1-4,7,8	5	6
1	MB	RB	RB	31	HB(1,4L), 3MB,7MB	RB	RB
2	HB	RB	RB	32	HB(7L)	SB	MB
3	HB	RB	RB(L)	33	HB	MB	MB
4	HB	MB	MB	34	HB(3L)	MB	MB
5	HB	MB	MB	35	HB(2L)	MB	MB
6	HG	MB	MB	36	HG(2L)	SB	MB
7	HG	MB	MB	37	HG	MB	MB
8	HG	MB	MB	38	HG	MB	MB
9	HG(2L)	MB	MB	39	HG(1,2L)	MB	MB
10	HG	MB	AN	40	HG(1L)	MB	MB
11	BOM	BOM	BOM	41	BOM	MB	MB
12	BOM	MB	MB	42	BOM	MB	MB
13	BOM	MB	MB	43	BOM	RB	RB(L)
14	BOM	MB	MB	44	BOM	HB	HB
15	BOM	RB	RB	45	BOM	HB	HG
16	HB	MB	MB	46	HB(1L)	RB	RB
17	HB	MB	MB	47	HB(2,7L)	HB	HB
18	HB	MB	MB	48	HB(4L)	HB	HB
19	HB	MB	MB	49	HB(7L)	HB	HB(L)
20	HB	HB	MB	50	HB	HG	AN
21	HG	MB	MB	51	HG	—	—
22	HG	MB	MB	52	HG	HB	HB
23	HG	MB	MB	53	HG	HB	HB
24	HG	MB	MB	54	HG	—	—
25	HG	MB	MB	55	HG	HG	HB
26	BOM	MB	MB	56	BOM	HB	HG
27	BOM	MB	MB	57	BOM	HB	HG
28	BOM	RB(L)	RB	58	BOM	HB	HB
29	BOM	MB	MB	59	BOM	HB	HB
30	BOM	MB	AN				

continued

Table A-1. Continued

Section	Flange Holes 1-4,7,8	Flange Holes 5	Flange Holes 6
60	BOM	HGL	HB
61	HB	RB	RB
62	HB(2,3,7L)	HB	HG
63	HG	HG	HG
64	HB(7L)	–	–
65	HB(8L)	HG	HB
66	HG	HG	HB(L)
67	HG	HG	HB
68	HG	HG	HG
69	HG,1MB(L)	HG	HG
70	HG,1MB(L)	–	AN
71	BOM	HG	HG
72	BOM	HB	HG
73	BOM	HB	HG
74	BOM	–	HG
75	BOM	RB	HG
76	HB	–	HB
77	HB,1MB	–	–
78	HB(4,7,L)	HB	HB(L)
79	HB(4L)	RB	RB
80	HB	HB	HB
81	HG	HB	HB
82	HG	–	–
83	HG	HB	HB
84	HG,1SB	–	–
85	BOM	HB	HB
86	BOM	HB	HB
87	BOM	RB	RB
88	BOM	HB	RB
89	1,2,3,7,BOM	HB	–
90	HB	HB	AN
91	HB(1L)	HB	HB
92	HB	–	–
93	HB(1L)	–	–
94	HG	–	HB
95	HG	HB	HB
96	HB	HB	HB
97	HG	MB	HB
98	HG	RB	RB

BOM – Huck fastener
SB – Stainless steel nut and bolt
HB – Hi Shear stainless steel
HG – Hi Shear mild steel
MB – Mild steel nut and bolt
(L) – Fastener loose
RB – Rock bolt
AN – Anode attached with stainless nut and bolt



APPENDIX B

SEMIANNUAL INSPECTIONS

In November 1976, the first of ten semiannual inspections was conducted. Visual inspection of the installation revealed that numerous jumper cables had been broken. All the jumpers were broken or missing between sections 1 and 35. Additional broken jumpers were found between sections 44 and 45, 60 and 61, and 77 and 78. The wires connecting the anodes to the pipe at sections 10, 30, and 90 were broken, and the anodes connected to sections 10 and 30 could not be located. The three anodes that were found were weighed in the water to determine the amount of anode consumption. These data are presented in Table B-1.

Galvanic potential readings were obtained with an underwater voltmeter; the results are presented in Figure B-1. Because of the numerous broken jumpers and disconnected anodes, only sections 45 through 78 are being protected.

Table B-1. Anode Consumption Rate

Section No.	Original Weight (lb, in water)	Weight After Six Months (lb, in water)	Weight Loss (lb)	No. of Sections Protected	Average Annual Loss Per Pipe Section (lb/yr)
10	64	–	–	–	–
30	64	–	–	–	–
50	64	57	7	15	1
70	64	53	9	19	1
90	64	62	2	–	–

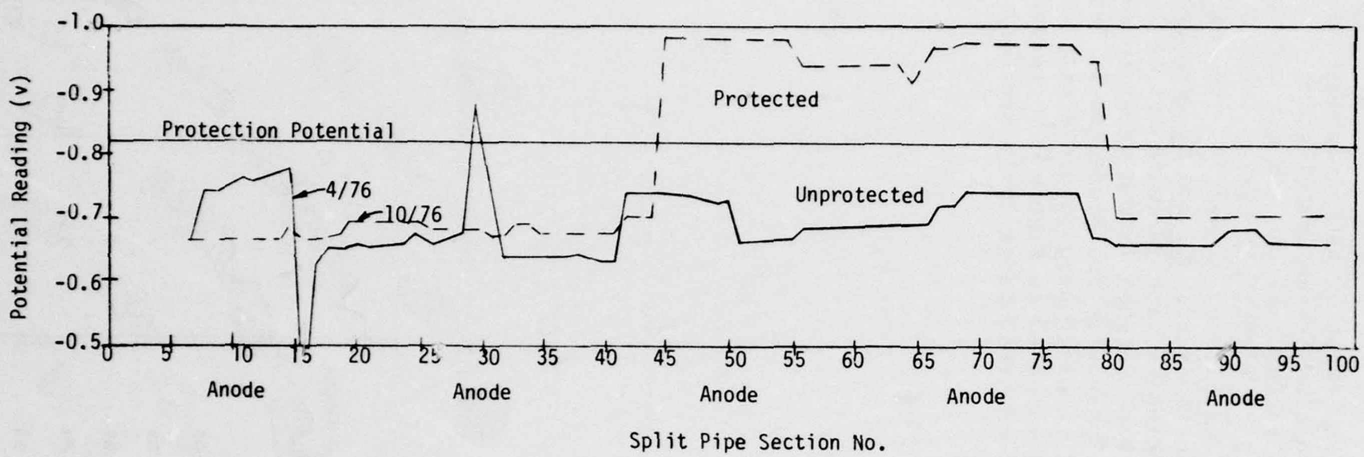


Figure B-1. Cathodic Protection Potential

DISTRIBUTION LIST

AFB CESCH, Wright-Patterson
ARCTICSUBLAB Code 54T, San Diego, CA
ARMY BMDSC-RE (H. McClellan) Huntsville AL
ARMY COASTAL ENGR RSCH CEN Fort Belvoir VA; R. Jachowski, Fort Belvoir VA
ARMY CORPS OF ENGINEERS MRD-Eng. Div., Omaha NE; Seattle Dist. Library, Seattle WA
ARMY CRREL A. Kovacs, Hanover NH
ARMY ENVIRON. HYGIENE AGCY Water Qual Div (Doner), Aberdeen Prov Ground, MD
ARMY MATERIALS & MECHANICS RESEARCH CENTER Dr. Lenoe, Watertown MA
ARMY MOBIL EQUIP R&D COM Mr. Cevasco, Fort Belvoir MD
ASST SECRETARY OF THE NAVY Spec. Assist Energy (P. Waterman), Washington DC; Spec. Assist Submarines, Washington DC
BUREAU OF RECLAMATION Code 1512 (C. Selander) Denver CO
CINCLANT Civil Engr. Supp. Plans. Ofr Norfolk, VA
CNO Code NOP-964, Washington DC; Code OPNAV 09B24 (H); Code OPNAV 22, Wash DC; Code OPNAV 23, Wash DC; OP987J (J. Boosman), Pentagon
COMCBPAC Operations Off, Makalapa HI
COMSUBDEVGRUONE Operations Offr, San Diego, CA
DEFENSE DOCUMENTATION CTR Alexandria, VA
DOE Dr. Cohen
HEDSUPPACT PWO, Taipei, Taiwan
MCAS Facil. Engr. Div. Cherry Point NC; CO, Kaneohe Bay HI; J. Taylor, Iwakuni Japan
MCRD PWO, San Diego Ca
NAF PWO, Atsugi Japan
NAS Code 18700, Brunswick ME; Dir. Util. Div., Bermuda; ENS Buchholz, Pensacola, FL; PWD Maint. Div., New Orleans, Belle Chasse LA; PWO Belle Chasse, LA; PWO Key West FL; PWO, Glenview IL; SCE Norfolk, VA
NATL RESEARCH COUNCIL Naval Studies Board, Washington DC
NAVACT PWO, London UK
NAVAEROSPREGMEDCEN SCE, Pensacola FL
NAVAL FACILITY PWO, Barbados; PWO, Centerville Bch, Ferndale CA
NAVCOASTSYSLAB Code 715 (J. Mittleman) Panama City, FL; Code 715 (J. Quirk) Panama City, FL; Library Panama City, FL
NAVCOMMAREAMSTRSTA SCE Unit 1 Naples Italy
NAVCOMMSTA Code 401 Nea Makri, Greece; PWO, Adak AK; PWO, Exmouth, Australia
NAVCONSTRACEN Code 74000 (Bodwell) Port Hueneme, CA
NAVEDTRAPRODEVCEN Tech. Library
NAVELEXSYSCOM Code PME-124-61, Washington DC
NAVENVIRHLTHCEN CO, Cincinnati, OH
NAVEODFAC Code 605, Indian Head MD
NAVFACENGCOM Code 043 Alexandria, VA; Code 044 Alexandria, VA; Code 0451 Alexandria, VA; Code 0453 (D. Potter) Alexandria, VA; Code 0454B Alexandria, Va; Code 04B5 Alexandria, VA; Code 101 Alexandria, VA; Code 1023 (T. Stevens) Alexandria, VA; Morrison Yap, Caroline Is.; PC-22 (E. Spencer) Alexandria, VA; PL-2 Ponce P.R. Alexandria, VA
NAVFACENGCOM - CHES DIV. Code FPO-1 (C. Bodey) Wash, DC; Code FPO-1 (Ottsen) Wash, DC; Code FPO-1C21 Wash, DC; Code FPO-1P4 (Gregory); Code FPO-1SP (Dr. Lewis) Wash, DC; Code FPO-1SP13 (T F Sullivan) Wash, DC; Code FPO-IP12 (Mr. Scola), Washington DC
NAVFACENGCOM - LANT DIV. RDT&ELO 09P2, Norfolk VA
NAVFACENGCOM - NORTH DIV. (Boretsky) Philadelphia, PA; CO; Code 1028, RDT&ELO, Philadelphia PA; ROICC, Contracts, Crane IN
NAVFACENGCOM - PAC DIV. Code 09DG (Donovan), Pearl Harbor, HI; Code 402, RDT&E, Pearl Harbor HI
NAVFACENGCOM - SOUTH DIV. Code 90, RDT&ELO, Charleston SC
NAVFACENGCOM - WEST DIV. Code 04B; RDT&ELO Code 2011 San Bruno, CA
NAVFACENGCOM CONTRACT Eng Div dir, Southwest Pac, Manila, PI; OICC, Southwest Pac, Manila, PI
NAVHOSP LT R. Elsbernd, Puerto Rico
NAVOCEANO Code 1600 Bay St. Louis, MS; Code 3408 (J. Kravitz) Bay St. Louis
NAVOCEANSYSCEN Code 2010 San Diego, CA; Code 409 (D. G. Moore), San Diego CA; Code 4473 Bayside

Library, San Diego, CA; Code 52 (H. Talkington) San Diego CA; Code 5204 (J. Stachiw), San Diego, CA; Code 5214 (H. Wheeler), San Diego CA; Code 5224 (R.Jones) San Diego CA; Code 5311(T) (E. Hamilton) San Diego CA; Code 6565 (Tech. Lib.), San Diego CA; Code 7511 (PWO) San Diego, CA
NAVPGSCOL D. Leipper, Monterey CA; E. Thornton, Monterey CA
NAVPHIBASE CO, ACB 2 Norfolk, VA; Code S3T, Norfolk VA; Harbor Clearance Unit Two, Little Creek, VA; OIC, UCT ONE Norfolk, Va
NAVREGMEDCEN SCE (D. Kaye); SCE, Guam
NAVSCOLCECOFF C35 Port Hueneme, CA
NAVSEASYSCOM Code OOC (LT R. MacDougal), Washington DC; Code SEA OOC Washington, DC
NAVSEC Code 6034 (Library), Washington DC
NAVSHIPYD; Code 440 Portsmouth NH; Code 440, Puget Sound, Bremerton WA; Tech Library, Vallejo, CA
NAVSTA PWD (LTJG.P.M. Motolenich), Puerto Rico; PWO, Mayport FL; Utilities Engr Off. (LTJG A.S. Ritchie), Rota Spain
NAVSTA BISHOPS POINT Harbor Clear. Unit one, Pearl Harbor, HI
NAVSUBSCOL LT J.A. Nelson Groton, CT
NAVSUPPACT Code 413, Seattle WA; LTJG McGarrah, Vallejo CA
NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
NAVTECHTRACEN SCE, Pensacola FL
NAVWPNCEN Code 2636 (W. Bonner), China Lake CA
NAVWPNSTA EARLE PW Office (Code 09C1) Yorktown, VA; PWO, Seal Beach CA
NAVWPNSUPPCEN Code 09 (Boennighausen) Crane IN
NAVXDIVINGU LT A.M. Parisi, Panama City FL
NCBC CEL (CAPT N. W. Petersen), Port Hueneme, CA; CEL AOIC Port Hueneme CA; Code 10 Davisville, RI; Code 156, Port Hueneme, CA
NOAA Librarym Rockville, MD
NORDA Code 410 Bay St. Louis, MS; Code 440 (Ocean Rsch Off) Bay St. Louis MS
NRL Code 8441 (R.A. Skop), Washington DC; Rosenthal, Code 8440, Wash. DC
NSD SCE, Subic Bay, R.P.
NAVOCEANSYSCEN Hawaii Lab (D. Moore), Hawaii
NUSC Code 131 New London, CT; Code EA123 (R.S. Munn), New London CT; Code TA131 (G. De la Cruz), New London CT
OCEANAV Mangmt Info Div., Arlington VA
OCEANSYSLANT LT A.R. Giancola, Norfolk VA
ONR CDR Harlett, Boston MA; BROFF, CO Boston MA; Code 481, Arlington VA; Code 481, Bay St. Louis, MS; Code 700F Arlington VA; Dr. A. Laufer, Pasadena CA
PHIBCB 1 P&E, Coronado, CA
PMTC EOD Mobile Unit, Point Mugu, CA; Pat. Counsel, Point Mugu CA
PWC CO Norfolk, VA; CO, Great Lakes IL; Code 116 (LTJG. A. Eckhart) Great Lakes, IL; Code 120C (Library) San Diego, CA; Code 220.1, Norfolk VA; Code 30C (Boettcher) San Diego, CA; Code 400, Pearl Harbor, HI
U.S. MERCHANT MARINE ACADEMY Kings Point, NY (Reprint Custodian)
US DEPT OF INTERIOR Bureau of Land MNGMNT - Code 733 (T.E. Sullivan) Wash, DC
US GEOLOGICAL SURVEY Off. Marine Geology, Piteleki, Reston VA
US NATIONAL MARINE FISHERIES SERVICE Highlands NY (Sandy Hook Lab-Library)
USCG (G-ECV) Washington Dc; (G-MP-3/USP/82) Washington Dc
USCG ACADEMY LT N. Stramandi, New London CT
USCG R&D CENTER CO Groton, CT; D. Motherway, Groton CT; LTJG R. Dair, Groton CT
USNA Ocean Sys. Eng Dept (Dr. Monney) Annapolis, MD; PWD Engr. Div. (C. Bradford) Annapolis MD
CALIF. MARITIME ACADEMY Vallejo, CA (Library)
CALIFORNIA STATE UNIVERSITY LONG BEACH, CA (CHELAPATI); LONG BEACH, CA (YEN)
CATHOLIC UNIV. Mech Engr Dept, Prof. Niedzwecki, Wash., DC
DAMES & MOORE LIBRARY LOS ANGELES, CA
DUKE UNIV MEDICAL CENTER B. Muga, Durham NC
FLORIDA ATLANTIC UNIVERSITY BOCA RATON, FL (MC ALLISTER)
FLORIDA ATLANTIC UNIVERSITY Boca Raton FL (W. Tessin)
IOWA STATE UNIVERSITY Ames IA (CE Dept, Handy)
LEHIGH UNIVERSITY BETHLEHEM, PA (MARINE GEOTECHNICAL LAB., RICHARDS); Bethlehem PA (Linderman Lib. No.30, Flecksteiner)
LIBRARY OF CONGRESS WASHINGTON, DC (SCIENCES & TECH DIV)

MAINE MARITIME ACADEMY (Wyman) Castine ME; CASTINE, ME (LIBRARY)
MICHIGAN TECHNOLOGICAL UNIVERSITY Houghton, MI (Haas)
MIT Cambridge MA; Cambridge MA (Rm 10-500, Tech. Reports, Engr. Lib.)
NATL ACADEMY OF ENG. ALEXANDRIA, VA (SEARLE, JR.)
OREGON STATE UNIVERSITY (CE Dept Grace) Corvallis, OR; CORVALLIS, OR (CE DEPT, BELL); Corvalis OR (School of Oceanography)
PURDUE UNIVERSITY Lafayette IN (Leonards); Lafayette, IN (Altschaeffl); Lafayette, IN (CE Engr. Lib)
SAN DIEGO STATE UNIV. I. Noorany San Diego, CA
SCRIPPS INSTITUTE OF OCEANOGRAPHY LA JOLLA, CA (ADAMS)
SEATTLE U Prof Schwaegler Seattle WA
SOUTHWEST RSCH INST King, San Antonio, TX
STANFORD UNIVERSITY Engr Lib, Stanford CA; STANFORD, CA (DOUGLAS)
TEXAS A&M UNIVERSITY COLLEGE STATION, TX (CE DEPT); College Station TX (CE Dept. Herbich)
UNIVERSITY OF CALIFORNIA BERKELEY, CA (CE DEPT, GERWICK); BERKELEY, CA (CE DEPT, MITCHELL); Berkeley CA (Dept of Naval Arch.); Berkeley CA (E. Pearson); DAVIS, CA (CE DEPT, TAYLOR); La Jolla CA (Acq. Dept, Lib. C-075A); SAN DIEGO, CA, LA JOLLA, CA (SEROCKI)
UNIVERSITY OF DELAWARE LEWES, DE (DIR. OF MARINE OPERATIONS, INDERBITZEN); Newark, DE (Dept of Civil Engineering, Chesson)
UNIVERSITY OF HAWAII HONOLULU, HI (SCIENCE AND TECH. DIV.)
UNIVERSITY OF ILLINOIS Metz Ref Rm, Urbana IL; URBANA, IL (DAVISSON); URBANA, IL (LIBRARY)
UNIVERSITY OF MASSACHUSETTS (Heronemus), Amherst MA CE Dept
UNIVERSITY OF MICHIGAN Ann Arbor MI (Richart)
UNIVERSITY OF NEBRASKA-LINCOLN Lincoln, NE (Ross Ice Shelf Proj.)
UNIVERSITY OF NEW HAMPSHIRE DURHAM, NH (LAVOIE)
UNIVERSITY OF RHODE ISLAND Narragansett RI (Pell Marine Sci. Lib.)
UNIVERSITY OF SO. CALIFORNIA Univ So. Calif
UNIVERSITY OF TEXAS Inst. Marine Sci (Library), Port Arkansas TX
UNIVERSITY OF WASHINGTON SEATTLE, WA (APPLIED PHYSICS LAB); Seattle WA (E. Linger)
ALFRED A. YEE & ASSOC. Honolulu HI
AMETEK Offshore Res. & Engr Div
AMSCO Dr. R. McCoy, Erie, PA
ARCAIR CO. D. Young, Lancaster OH
ATLANTIC RICHFIELD CO. DALLAS, TX (SMITH)
USNA Sys. Engr. Dept (R. McCoy) Annapolis, MD
BECHTEL CORP. SAN FRANCISCO, CA (PHELPS)
BELGIUM HAECON, N.V., Gent
BRAND INDUS SERV INC. J. Buehler, Hacienda Heights CA
BRITISH EMBASSY Sci. & Tech. Dept. (J. McAuley), Washington DC
BROWN & CALDWELL E M Saunders Walnut Creek, CA
BROWN & ROOT Houston TX (D. Ward)
CANADA Can-Dive Services (English) North Vancouver; Library, Calgary, Alberta; Lockheed Petro. Serv. Ltd, New Westminster B.C.; Lockheed Petrol. Srv. Ltd., New Westminster BC; Mem Univ Newfoundland (Chari), St Johns; Surveyor, Nenninger & Chenevert Inc., Montreal
CHEVRON OIL FIELD RESEARCH CO. LA HABRA, CA (BROOKS)
COLUMBIA GULF TRANSMISSION CO. HOUSTON, TX (ENG. LIB.)
CONCRETE TECHNOLOGY CORP. TACOMA, WA (ANDERSON)
DRAVO CORP Pittsburgh PA (Giannino)
NORWAY DET NORSKE VERITAS (Library), Oslo
EXXON PRODUCTION RESEARCH CO Houston, TX (Chao)
FRANCE Dr. Dutertre, Boulogne; P. Jensen, Boulogne; Roger LaCroix, Paris
GRUMMAN AEROSPACE CORP. Bethpage NY (Tech. Info. Ctr)
MAKAI OCEAN ENGRNG INC. Kailua, HI
LAMONT-DOHERTY GEOLOGICAL OBSERV. Palisades NY (Selwyn)
LIN OFFSHORE ENGRG P. Chow, San Francisco CA
LOCKHEED MISSILES & SPACE CO. INC. Sunnyvale, CA (Phillips)
LOCKHEED OCEAN LABORATORY San Diego CA (F. Simpson)
MARATHON OIL CO Houston TX (C. Seay)
MC CLELLAND ENGINEERS INC Houston TX (B. McClelland)

MOBIL PIPE LINE CO. DALLAS, TX MGR OF ENGR (NOACK)
NORWAY A. Torum, Trondheim; DET NORSKE VERITAS (Roren) Oslo; I. Foss, Oslo; J. Creed, Ski; Norwegian Tech Univ (Brandtzaeg), Trondheim
OCEAN ENGINEERS SAUSALITO, CA (RYNECKI)
OCEAN RESOURCE ENG. INC. HOUSTON, TX (ANDERSON)
OFFSHORE DEVELOPMENT ENG. INC. BERKELEY, CA
PORTLAND CEMENT ASSOC. SKOKIE, IL (CORELY); SKOKIE, IL (KLIEGER); Skokie IL (Rsch & Dev Lab, Lib.)
RAYMOND INTERNATIONAL INC. E Colle Soil Tech Dept, Pennsauken, NJ
SCHUPACK ASSOC SO. NORWALK, CT (SCHUPACK)
SEATECH CORP. MIAMI, FL (PERONI)
SHELL DEVELOPMENT CO. Houston TX (C. Sellars Jr.)
SHELL OIL CO. HOUSTON, TX (MARSHALL); Houston TX (R. de Castongrene)
SWEDEN GeoTech Inst; VBB (Library), Stockholm
TIDEWATER CONSTR. CO Norfolk VA (Fowler)
UNITED KINGDOM British Embassy (Info. Offr), Washington DC; Cement & Concrete Assoc Wexham Springs, Slough Bucks; Cement & Concrete Assoc. (Library), Wexham Springs, Slough; D. New, G. Maunsell & Partners, London; Library, Bristol; R. Rudham Oxfordshire; Shaw & Hatton (F. Hansen), London; Taylor, Woodrow Constr (Stubbs), Southall, Middlesex; Univ. of Bristol (R. Morgan), Bristol
WATT BRIAN ASSOC INC. Houston, TX
WESTINGHOUSE ELECTRIC CORP. Annapolis MD (Oceanic Div Lib, Bryan)
WOODWARD-CLYDE CONSULTANTS PLYMOUTH MEETING PA (CROSS, III)
ADAMS, CAPT (RET) Irvine, CA
BRAHTZ La Jolla, CA
BULLOCK La Canada
R.F. BESIER Old Saybrook CT
ENERGY R&D ADMIN. H. Skowbo, Washington, DC
WM TALBOT Orange CA
CEC Donofrio, John L., LT